Biological Investigation of First-Year Sea Ice near Resolute Bay, Nunavut, Spring to Early Summer 2001

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Canadian Data Report of Hydrography and Ocean Sciences

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ABSTRACT

Michel, C., A. Riedel, and C.J. Mundy. 2003. Biological Investigation of First-Year Sea Ice near Resolute Bay, Nunavut, Spring to Early Summer 2001. Can. Data Rep. Hydrogr. Ocean Sci. 160: vi + 29 p.

The results presented in this report are from the first year of a three-year sampling project conducted at a first-year sea ice station near Resolute Bay, in the High Canadian Arctic. The overall objective of this project is to investigate seasonal and inter-annual variability in sea-ice associated primary production processes, with respect to the influence of climatic forcing variables and potential effects of climate warming in the Arctic. This report documents the biological data from three ecosystem compartments, i.e. the bottom ice, the water column, and the underice sinking biomass. The data include size-fractionated chlorophyll *a* biomass (total and > 5 μm), particulate organic carbon and nitrogen, biogenic silica, and dissolved organic carbon. Data from the three compartments are presented in figures as seasonal trends, and original datasets are summarized in appendices. A companion document (Riedel et al. 2003) provides complete lists and abundances of algal and protist species observed in the ice, the water column, and the sinking material.

RÉSUMÉ

Michel, C., A. Riedel, and C.J. Mundy. 2003. Biological Investigation of First-Year Sea Ice near Resolute Bay, Nunavut, Spring to Early Summer 2001. Can. Data Rep. Hydrogr. Ocean Sci. 160: vi + 29 p.

Les résultats présentés dans ce rapport proviennent de la première année d'échantillonnage d'un projet d'une durée de trois ans, ayant cours à une station de glace de première année près de Resolute, dans l'Arctique canadien. L'objectif général du projet est d'étudier la variabilité dans les processus de production primaire associée à la glace de mer, aux échelles saisonnière et inter-annuelle, et ce dans le contexte de l'influence de facteurs climatiques et du réchauffement de l'Arctique. Ce document présente des données biologiques provenant de trois compartiments de l'écosystème, i.e. la base de la glace, la colonne d'eau, et la biomasse qui sédimente sous la glace. Les données incluent la biomasse chlorophyllienne fractionnée (totale et > 5 μm), le carbone et l'azote organiques particulaires, la silice biogénique, et le carbone organique dissous. Les données des trois compartiments sont présentées sous forme de figures montrant les variations saisonnières, et les résultas originaux sont présentés en annexe. Un second rapport (Riedel et al. 2003) présente la liste complète des espèces ainsi que les abondances de cellules algales et de protistes observés dans la glace, la colonne d'eau, et la biomasse qui sédimente sous la glace.

INTRODUCTION

The data presented in this report contribute to our understanding of the variability of the seasonal cycle of primary production associated with Arctic first-year ice and its transfer to zooplankton and benthic grazers. Increased solar radiation during the Arctic spring allows for the development of high microalgae biomass in annual sea ice, especially within the bottom few centimeters of the ice matrix (i.e. bottom ice communities, see Horner 1985). This bloom of ice algae typically takes place prior to phytoplankton growth in the water column. Therefore, ice algae constitute an early food source for planktonic or benthic grazers when pelagic resources are limited (e.g. Conover et al. 1986; Runge and Ingram 1988). The ice algae and other materials present within annual sea ice are released into the water column at the time of ice melt, thus affecting carbon fluxes within the water column and towards the benthos.

Factors influencing sea ice primary productivity, which include solar radiation, temperature, inorganic nutrients and the presence of organisms and particulate matter within the ice and at the ice-water interface, are susceptible to potential effects of climate change. Predictions from GCMs indicate that the most pronounced effects of climate change will occur at northern latitudes (e.g. Stouffer et al. 1989; Flato et al. 2000). First-year sea ice represents ca. 50% of the total sea ice cover in the Northern Hemisphere (Maykut 1985). Ice algae production, which mainly takes place within annual sea ice, accounts for 25% or more of total Arctic primary production (Legendre et al. 1981; Gosselin et al. 1986). First-year sea ice is likely to be first and most extensively affected by climate warming. It is thus imperative to further our understanding of biological oceanographic processes associated with the presence of annual sea ice, and their relationship with climate and ice dynamics, in order to better predict and respond to potential ecosystem changes.

The data presented in this report summarize seasonal trends in biological variables within and underneath annual sea ice, in McDougall Sound (near Resolute Bay), during a two-month sampling period in spring and early summer (May - July) 2001. This period typically covers the time of high production by ice algae, as well as the onset of their release into the water column. The data reported are average values for each sampling date and depth, when applicable. The reliability of the data was assessed through various approaches including, for particulate organic carbon (POC) and particulate organic nitrogen (PON), the use of POC/PON and POC/chlorophyll *a* ratios and regression slopes to identify ambiguous data. POC and/or PON values were not included when POC/PON ratios were outside the range of the average ratio plus or minus two standard deviations. In the few cases when POC values only were removed, POC estimates were back-calculated using the average POC/PON ratio; these values are italicised in the appendices.

The authors would like to express a word of caution concerning the biogenic silica data. The biogenic silica was extracted through hydrolysis based on the method of Paasche (1980) and the silico-molybdate complex was then read at 810 nm. This method has been used routinely in our laboratory and analysis of replicate samples have typically resulted in very good repeatability (e.g. for sediment trap samples in the North Water Polynya, the average percent variation among replicates = 5%). However, results from the present analysis led to high variability among

duplicate samples. We used a different type of filter during this study (i.e. Millipore membrane filters *versus* Nuclepore polycarbonate filters), and these filters were prone to degradation during the extraction. We believe that this might have interfered with the colorimetric reaction. All data have been verified against other variables (POC, PON, chlorophyll *a*), and dubious values were removed. However, the biogenic silica data set should be used with some caution, and we recommend the use of Nuclepore polycarbonate filters for the extraction of biogenic silica.

MATERIAL AND METHODS

SAMPLING PROTOCOL

Sampling was conducted from 8 May to 6 July 2001 at an ice camp located in McDougall Sound, near Resolute, Nunavut, Canada (75°13.94'N, 97°00.24'W). All sampling was conducted at the camp and samples were processed immediately. First-year sea ice, water column and sediment trap samples were collected at three day intervals, yielding a total of 19 sampling dates for the ice and sediment traps, and 20 sampling dates for the water column.

Bottom ice samples were collected with a MARK II ice corer (9 cm internal diameter) at proximate sites with low (10.34 cm ± 9.61 cm) and high (25.41 cm ± 13.17 cm) snow cover depths. Three cores were taken at each snow depth site. The bottom 3 to 5 cm of the cores were cut and, for each snow depth, the three cores were pooled together in a dark isothermal container and slowly melted in surface seawater filtered on Whatman GF/F filters. The melted cores were subsampled for duplicate measurements of size-fractionated chlorophyll *a* (chl *a*) (total and > 5 µm), POC and PON, dissolved organic carbon (DOC), and biogenic silica (BioSi). Subsamples were also collected for the identification and enumeration of algal cells and protists.

The water column was sampled with 4 L Niskin bottles at depths of 2.5, 5, 10 and 25 m underneath the ice, at or around the time of low tide. Subsamples from each depth were processed for total and > 5 µm chl *a*, POC and PON, and BioSi. Subsamples from 2.5 m only were analyzed for DOC and for cell and protists identification and counts.

Short-term (3 day) sediment traps were deployed to characterize under ice sedimentation. Two series of traps were attached to the ice and installed at depths of 2.5, 5 and 25 m from the undersurface of the ice. The traps were PVC cylinders, 7.5 cm internal diameter, with an aspect ratio of 10. Upon deployment, the traps were filled with Whatman GF/F filtered seawater, without poison or preservative. A Falmouth 2D-ACM current meter was attached to one trap line to assess tilt and hydrodynamic effects on the collection efficiency of the traps. Upon recovery, the entire trap volume was transferred to a dark container. Trap subsamples from one trap line were taken for total and > 5 µm chl *a*, POC and PON, BioSi, and cell identification and counts. The other trap line was used for fecal pellet counts. The whole content of each trap was gently concentrated on a 50 µm mesh and the material was preserved with buffered formaldehyde, for later microscopic counts and size measurements of fecal pellets (results not reported).

LABORATORY ANALYSES

Chl *a* was determined fluorometrically on duplicate subsamples filtered onto Whatman GF/F filters (nominal pore size of 0.7μm). In addition, size-fractionated chl *a* (> 5 μm) was measured on subsamples filtered onto Nuclepore 5 μm filters. Chl *a* concentrations were calculated using equations of Holm-Hansen et al. (1965) after measuring fluorescence with a Sequoia-Turner fluorometer Model 450, following 24 h extraction in 90% acetone at 4°C in the dark (Parsons et al. 1989). Chl *a* measurements were carried out at the field camp.

All other subsamples were processed at the ice camp and brought back to the main laboratory for analyses, as described below. Subsamples for POC and PON, and BioSi analyses were immediately frozen in liquid nitrogen at the ice station, and kept frozen until analysis.

Subsamples for POC and PON were filtered onto pre-combusted GF/F Whatman filters, and later analyzed on a Perkin Elmer CHN analyzer. For BioSi, subsamples were filtered onto Millipore 0.45 μm membrane filters using a plastic filtration apparatus and kept frozen until analysed, according to the method of Paasche (1980), as modified by Ragueneau and Tréguer (1994). Colorimetric determination of silicate (Parsons et al. 1989) was performed at 810 nm on a Jenway 6300 spectrophotometer. Subsamples for algal cells and protist identification and counts were fixed in acidic Lugol's solution (details and results in companion report, Riedel et al. 2003).

DOC samples were pre-filtered through 0.22 μm sterile syringe filters and kept at 4°C in acid washed amber glass bottles with Teflon caps, after adding 50% v/v of H_3PO_4 (5 μL mL^{-1}), until analysis on a Shimadzu TOC-5000 analyzer.

RESULTS

Figures 1 and 2 show seasonal trends in areal concentrations of bottom ice chl *a* (total and > 5 μm) and POC and PON, respectively. Figure 3 brings together trends in areal concentrations of BioSi and DOC concentrations in the bottom ice.

Seasonal changes observed in the water column are shown in Figures 4, 5 and 6. These Figures show trends, at the four sampling depths, in chl *a* suspended biomass (total and > 5μm), POC and PON, and BioSi. DOC concentrations were measured, and are shown, only for 2.5 m (Figure 6).

Sinking fluxes underneath the ice are presented in Figures 7 , 8 and 9. Clear seasonal increases in chl *a* (Figure 7), POC and PON (Figure 8) and BioSi (Figure 9) were observed at 2.5, 5 and 25 m.

ACKNOWLEDGEMENTS

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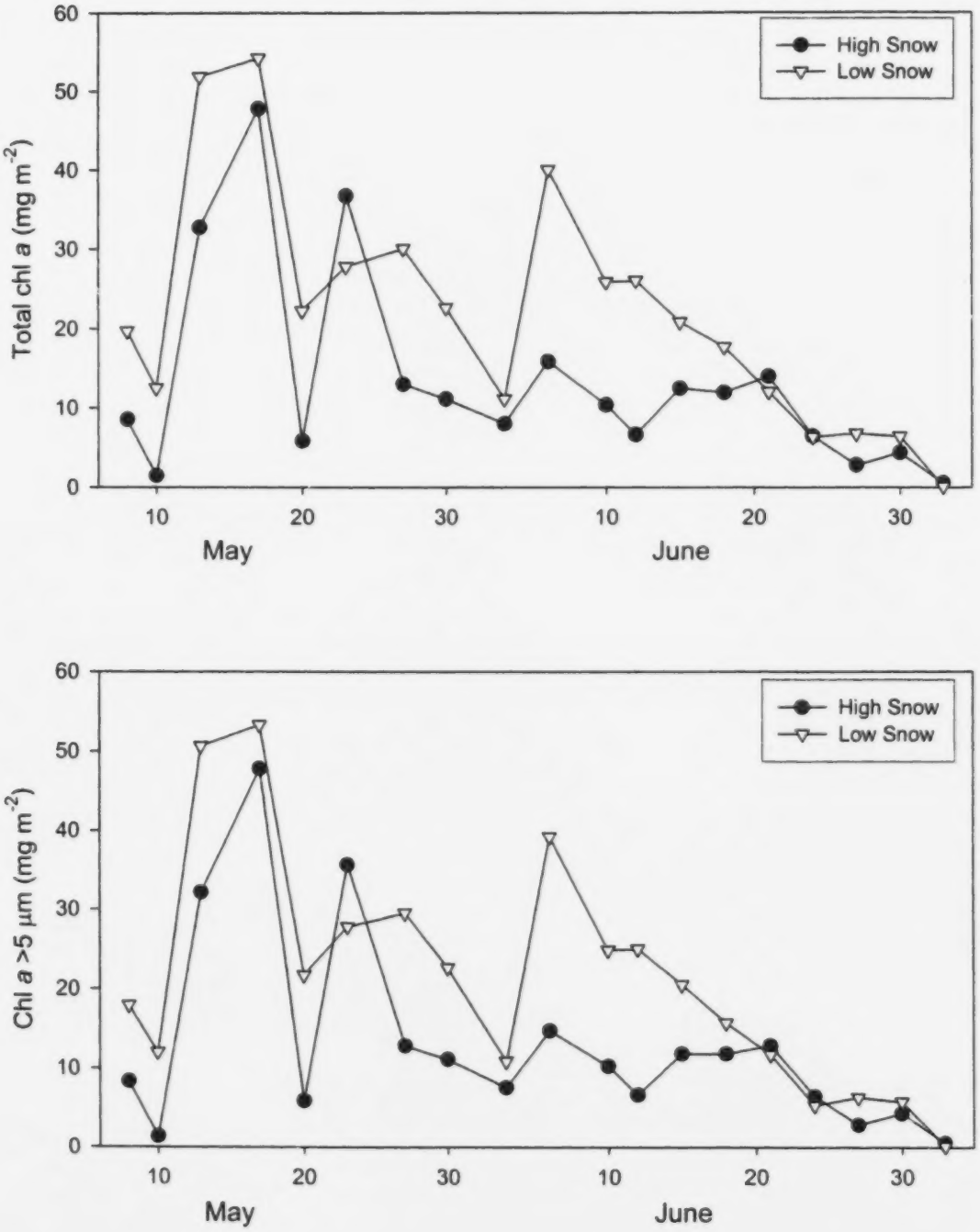

Figure 1. Seasonal trends in areal chlorophyll *a* (chl *a*) concentrations (total and > 5 µm) at the bottom of first-year sea ice, at sites with high and low snow depths, in McDougall Sound, 2001.

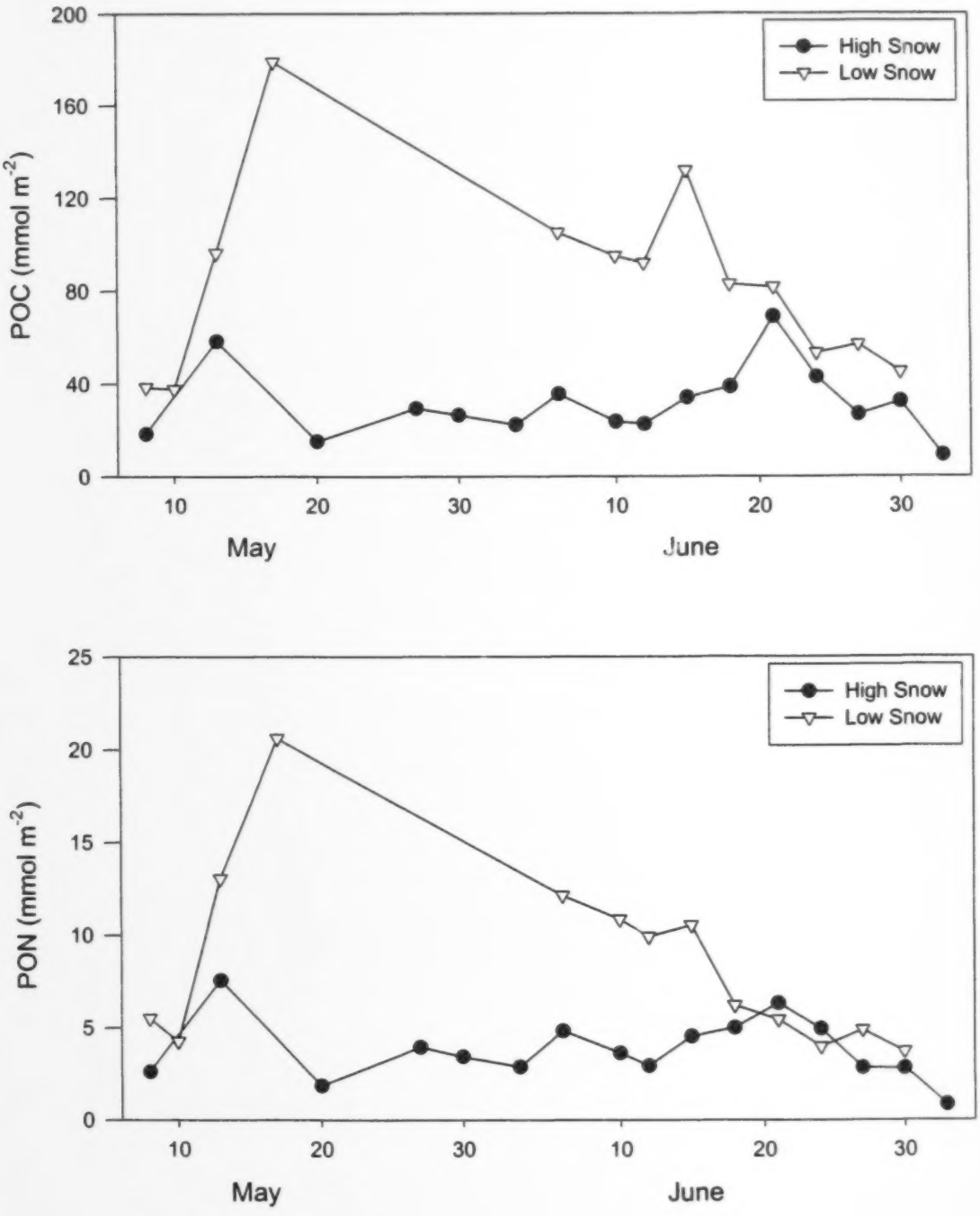

Figure 2. Seasonal trends in areal concentrations of particulate organic carbon (POC) and nitrogen (PON) at the bottom of first-year sea ice, at sites with high and low snow depths, in McDougall Sound, 2001.

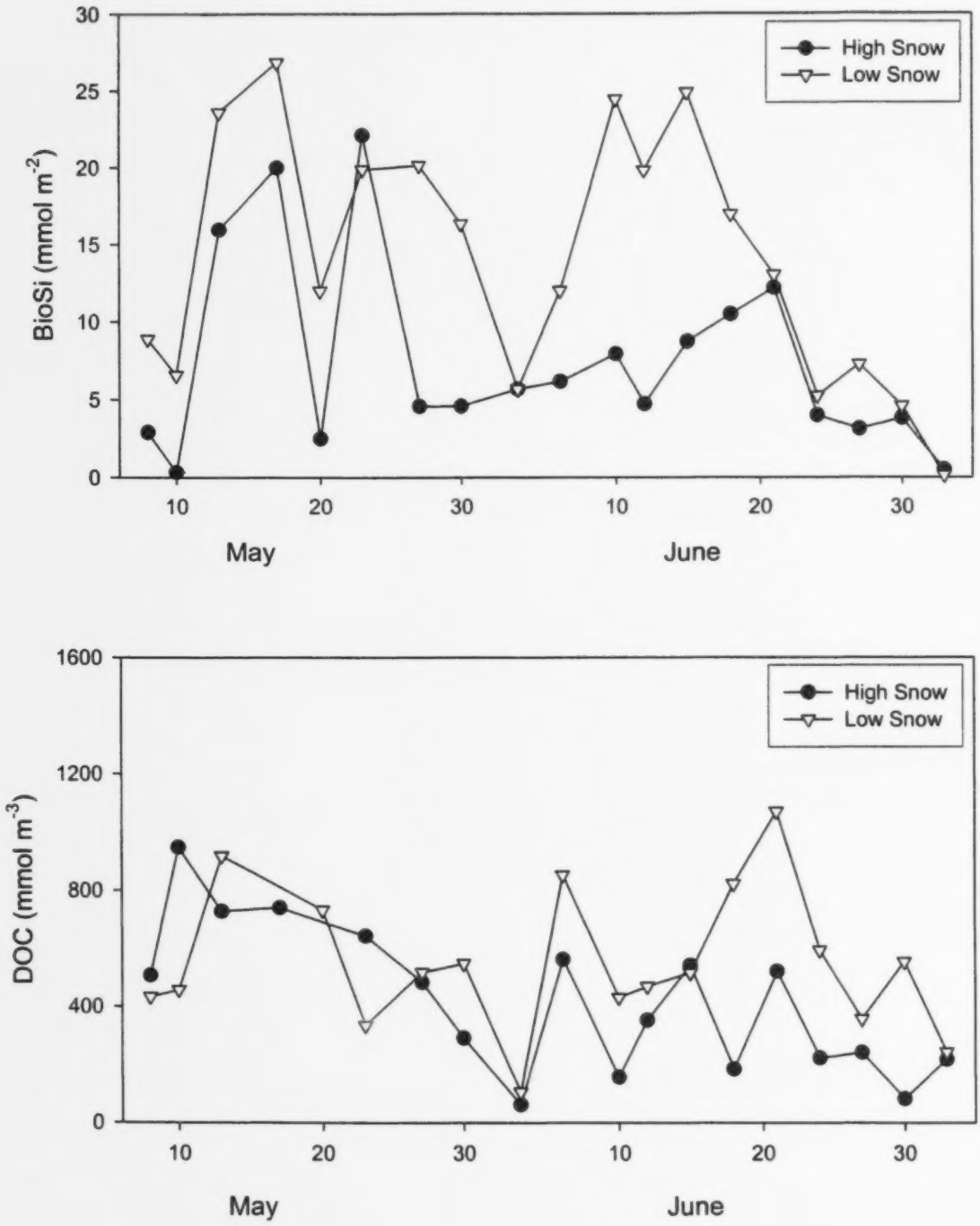

Figure 3. Seasonal trends in areal concentrations of biogenic silica (BioSi) and dissolved organic carbon (DOC) at the bottom of first-year sea ice, at sites with high and low snow depths, in McDougall Sound, 2001.

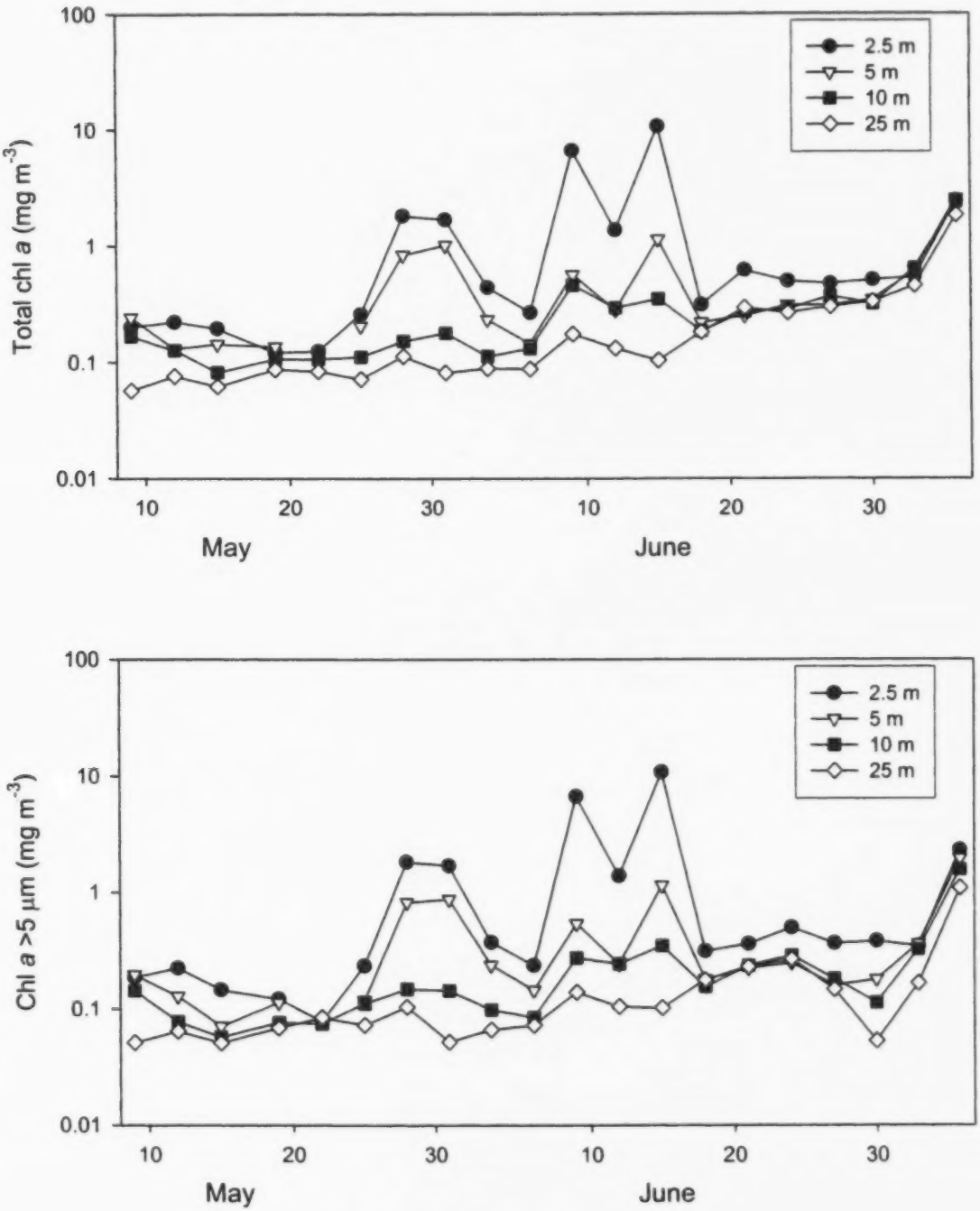

Figure 4. Seasonal trends in suspended chlorophyll *a* (chl *a*) concentrations (total and > 5 µm), at 2.5, 5, 10 and 25 m, in McDougall Sound, 2001. Y-axis is a log scale.

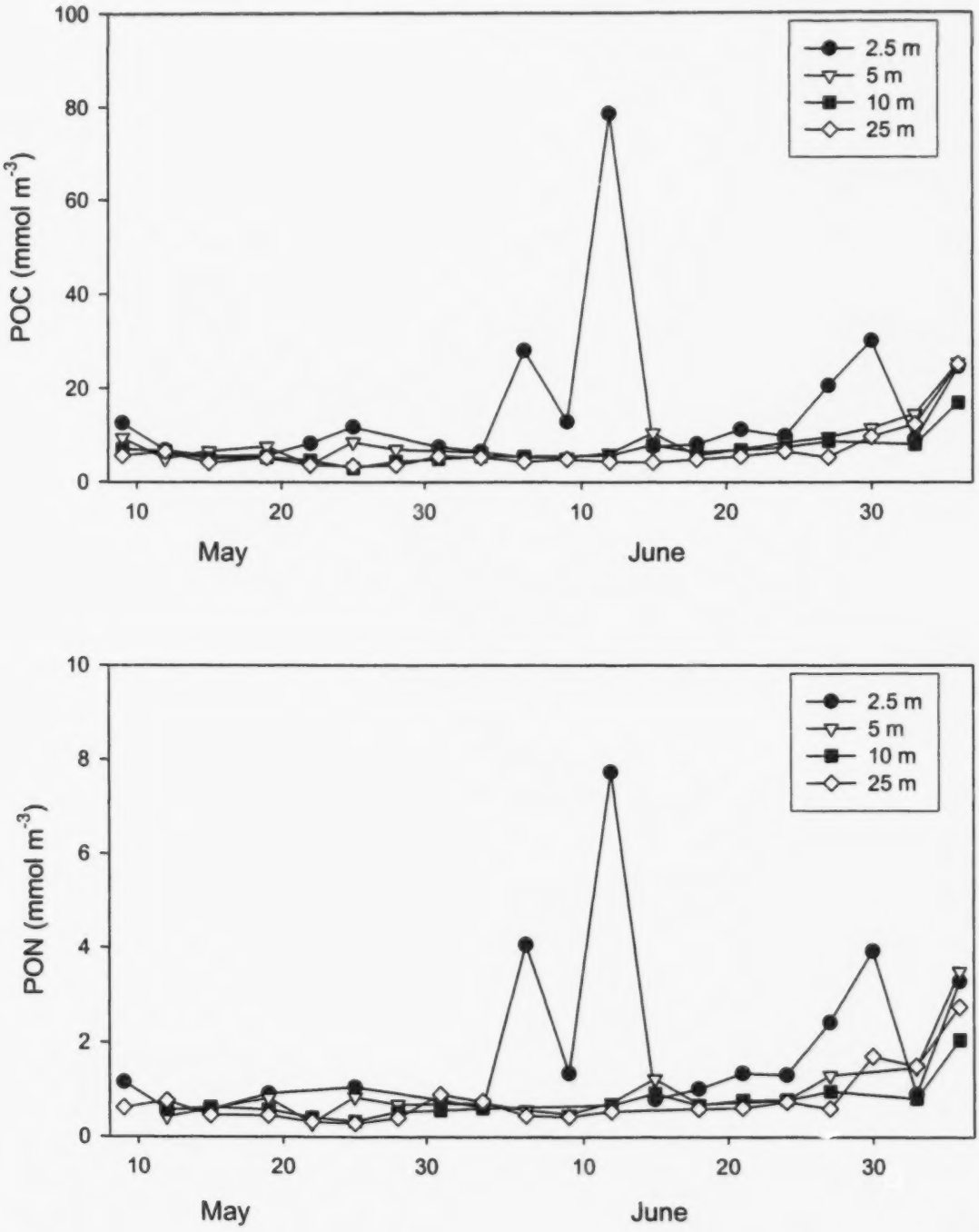

Figure 5. Seasonal trends in suspended concentrations of particulate organic carbon (POC) and nitrogen (PON) at 2.5, 5, 10 and 25 m, in McDougall Sound, 2001.

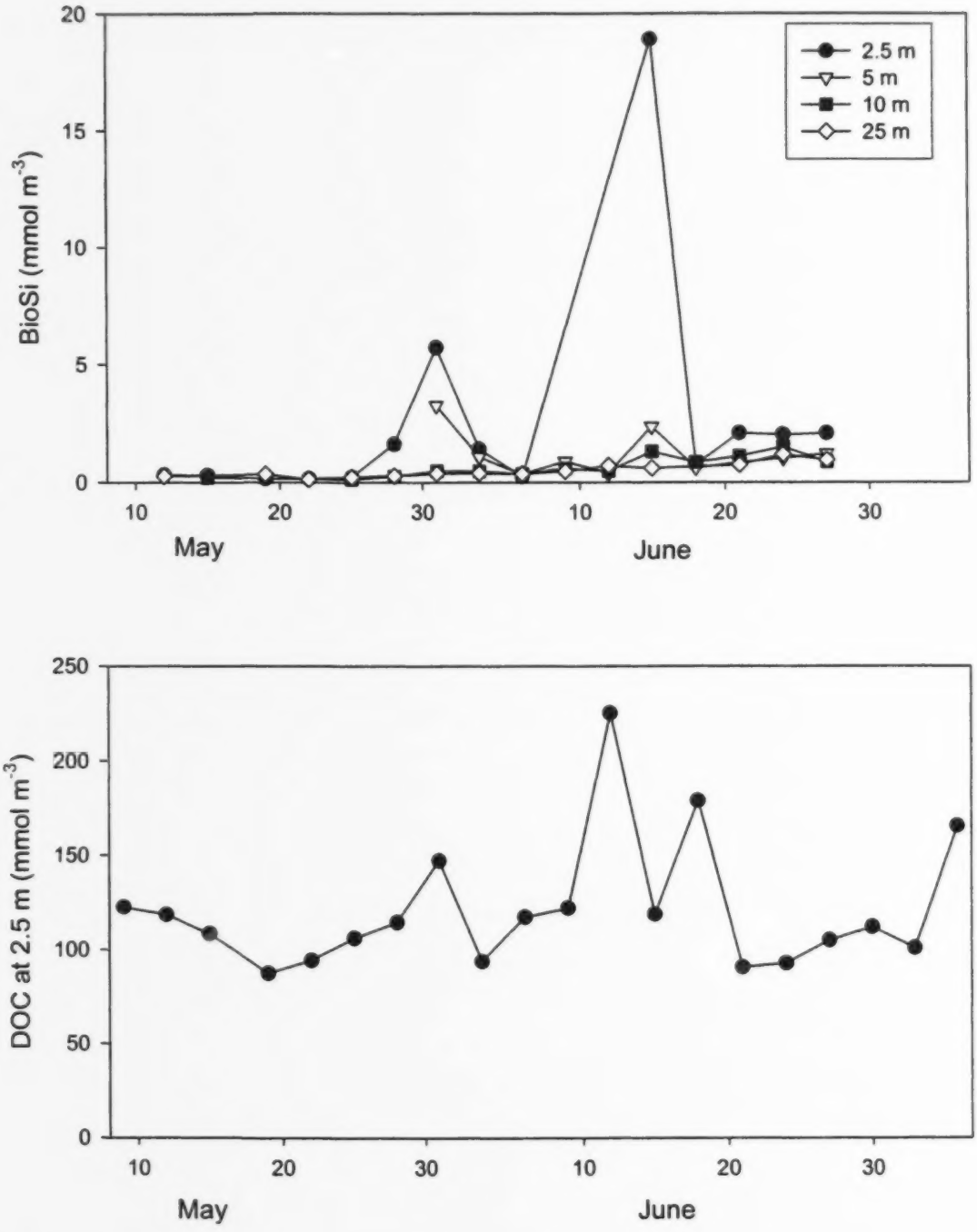

Figure 6. Seasonal trends in suspended concentrations of biogenic silica (BioSi) and dissolved organic carbon (DOC) (2.5 m only), in McDougall Sound, 2001.

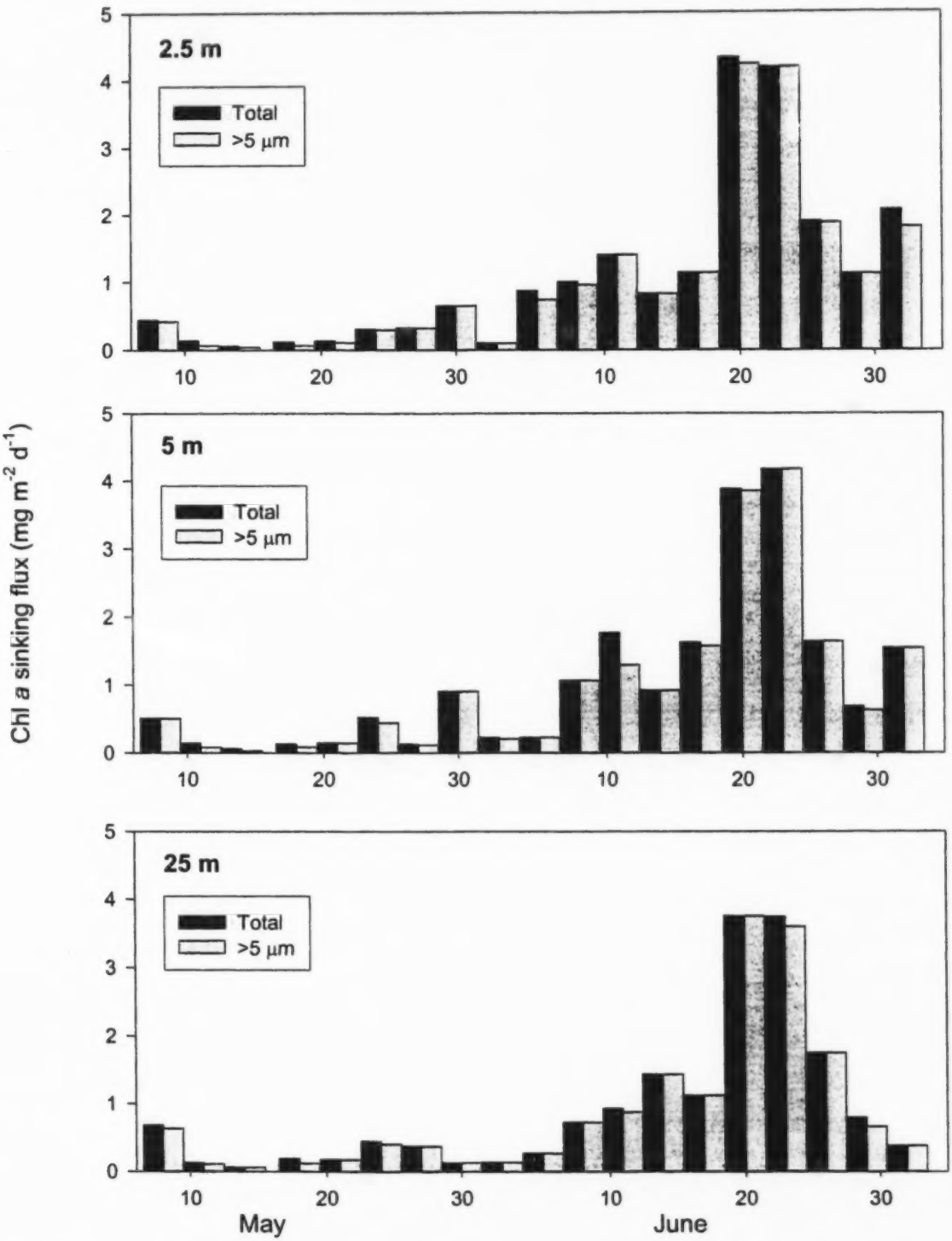

Figure 7. Seasonal trends in chlorophyll *a* (chl *a*) sinking fluxes (total and > 5 µm) at 2.5, 5 and 25 m underneath the ice, in McDougall Sound, 2001.

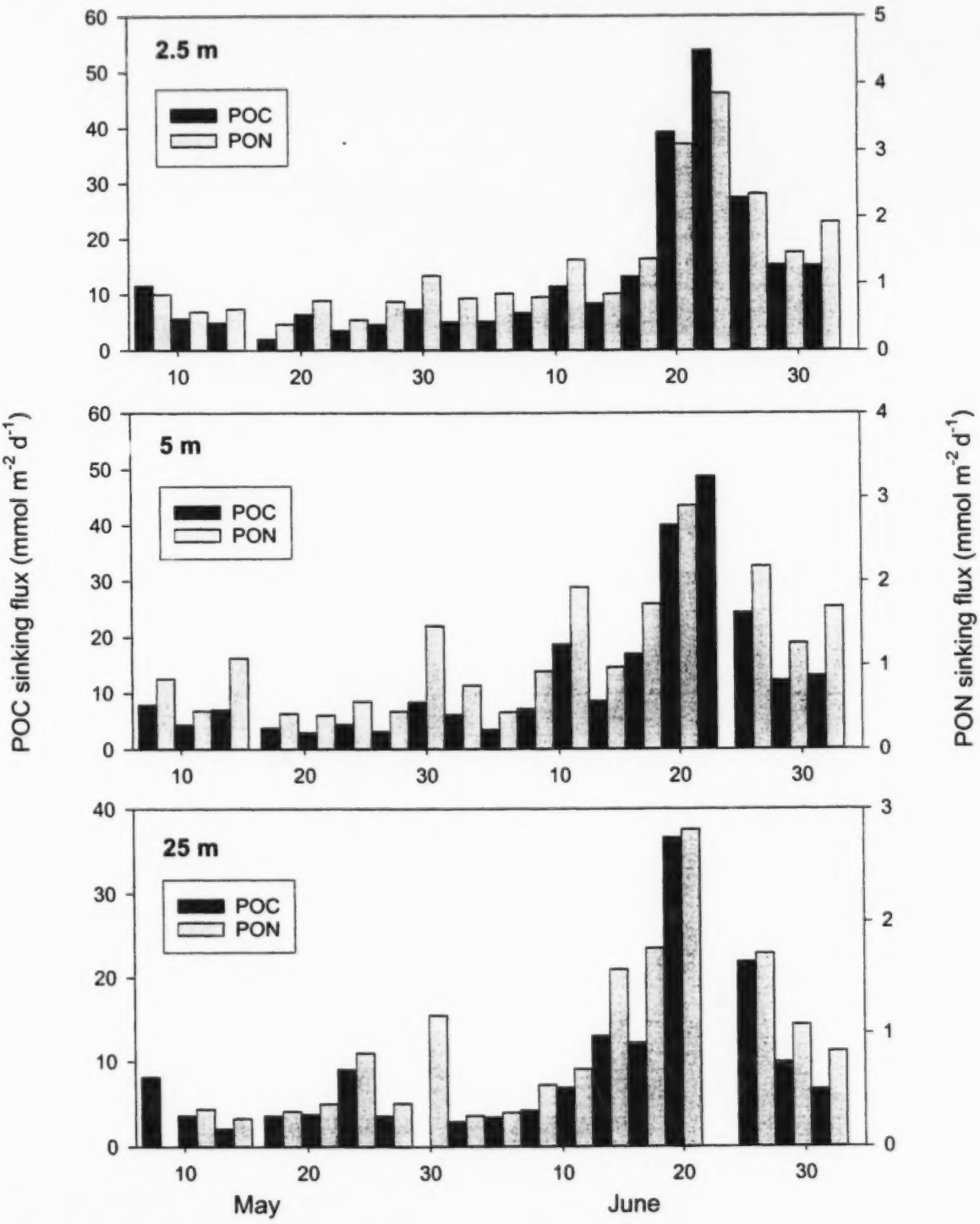

Figure 8. Seasonal trends in particulate organic carbon (POC) and nitrogen (PON) sinking fluxes at 2.5, 5 and 25 m underneath the ice, in McDougall Sound, 2001.

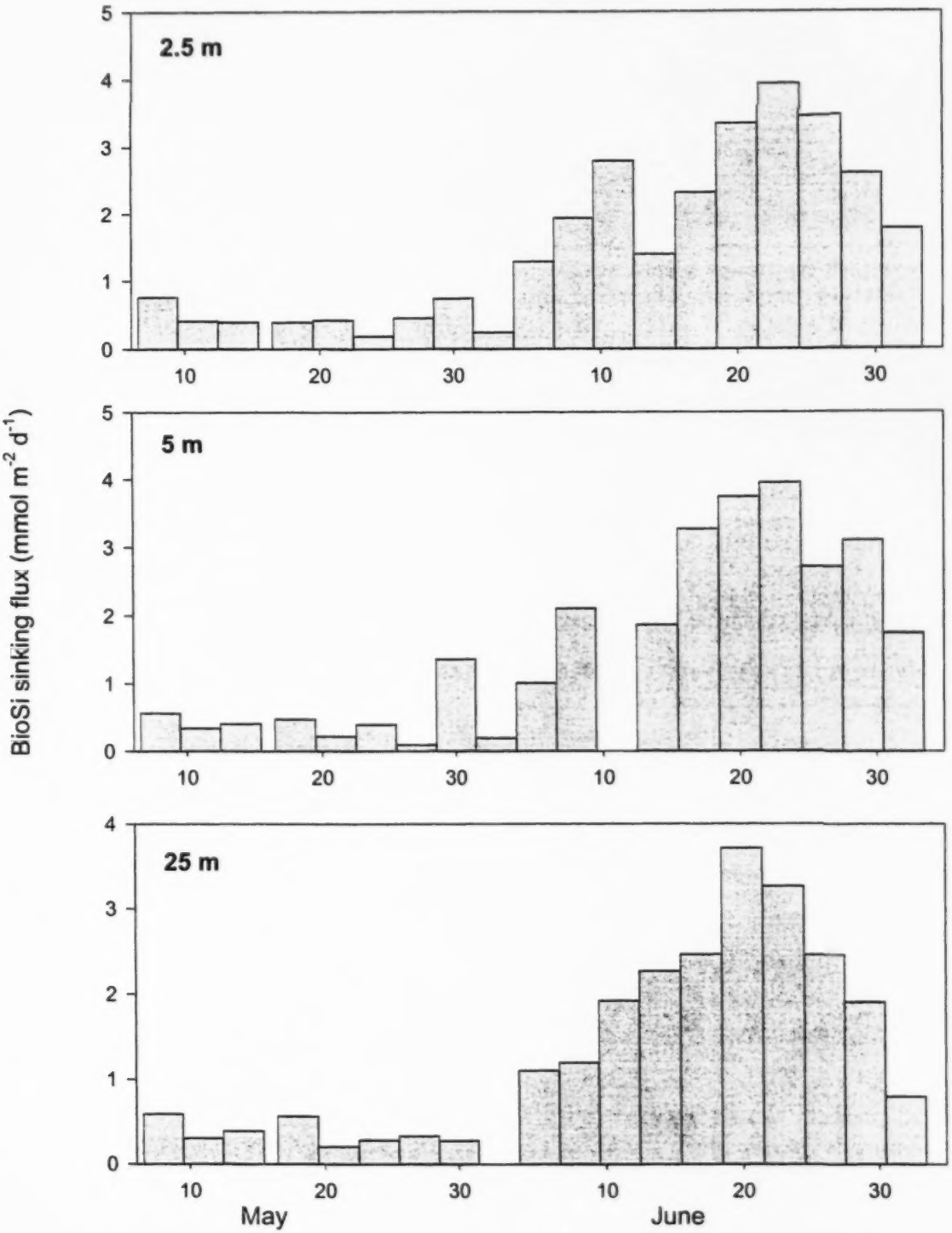

Figure 9. Seasonal trends in biogenic silica (BioSi) sinking fluxes at 2.5, 5 and 25 m underneath the ice, in McDougall Sound, 2001.

Appendix 1.
Summary of chlorophyll *a* concentrations in bottom ice (mg m^{-3}), under high and low snow depths at a first-year ice station in McDougall Sound, 2001. Averages (Avg) and standard deviations (SD) are given.

		Bottom Ice Chl *a* (mg m^{-3})							
		High Snow				Low Snow			
		Total		> 5 µm		Total		> 5 µm	
Sampling Date	Julian Date	Avg	SD	Avg	SD	Avg	SD	Avg	SD
5/8/2001	128	245.3	13.8	239.3	14.2	554.1	12.1	504.9	2.9
5/10/2001	130	50.9	2.4	46.3	2.7	347.6	9.3	333.6	14.5
5/13/2001	133	1020.7	43.1	1001.6	2.7	1678.3	11.5	1638.5	19.8
5/17/2001	137	1371.5	2.1	1374.6	2.1	1450.3	7.7	1424.0	24.6
5/20/2001	140	198.0	9.4	203.3	3.2	704.1	41.8	687.8	5.0
5/23/2001	143	1096.1	30.5	1062.3	13.1	900.0	13.4	897.7	4.6
5/26/2001	146	407.4	9.2	401.5	6.8	742.2	1.1	727.6	8.0
5/29/2001	149	312.9	10.0	312.6	7.1	648.4	9.7	658.6	8.1
6/1/2001	152	239.0	9.8	225.6	4.4	366.1	1.6	358.5	19.4
6/4/2001	155	468.2	2.2	436.1	2.9	1006.3	9.7	984.4	32.9
6/7/2001	158	348.6	1.4	343.7	4.6	848.6	36.3	815.0	32.6
6/10/2001	161	196.4	0.2	208.7	0.7	659.9	12.9	633.1	7.0

Appendix 1 Cont.

		Bottom Ice Chl *a* (mg m^{-3})							
		High Snow				Low Snow			
		Total		> 5 µm		Total		> 5 µm	
Sampling Date	Julian Date	Avg	SD	Avg	SD	Avg	SD	Avg	SD
6/13/2001	164	423.7	13.6	402.6	5.4	580.4	11.6	572.8	9.2
6/16/2001	167	410.2	4.1	407.0	1.0	561.1	62.3	499.6	11.8
6/19/2001	170	458.0	8.6	422.6	50.3	399.4	13.1	390.3	7.1
6/22/2001	173	212.7	2.6	217.0	6.2	224.9	3.0	187.5	7.9
6/25/2001	176	95.5	3.8	98.3	3.3	217.9	0.6	202.3	4.6
6/28/2001	179	170.3	5.2	166.6	8.5	226.7	5.3	203.4	9.9
7/1/2001	182	17.5	0.3	16.0	0.6	3.2	2.1	3.4	0.8

Appendix 2.
Summary of bottom ice concentrations of particulate organic carbon and nitrogen, dissolved organic carbon, and biogenic silica (mmol m^{-3}) under high and low snow depths at a first-year ice station in McDougall Sound, 2001. Averages (Avg) and standard deviations (SD) are given when applicable. nd: no data

		High Snow						Low Snow					
Sampling Date	Julian Date	POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})		BioSi (mmol m^{-3})		POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})		BioSi (mmol m^{-3})	
				Avg	SD	Avg	SD			Avg	SD	Avg	SD
5/8/2001	128	531.7	75.2	507.1	7.6	83.9	1.2	1087.8	155.0	432.2	4.3	250.0	nd
5/10/2001	130	nd	nd	947.2	15.2	11.6	0.4	1050.1	118.6	457.1	1.5	182.7	nd
5/13/2001	133	1819.5	235.8	727.0	3.0	497.5	72.8	3121.9	421.6	916.9	10.8	763.6	129.8
5/17/2001	137	nd	nd	739.5	11.2	573.8	41.9	4782.1	550.5	nd	49.5	717.8	18.9
5/20/2001	140	519.1	62.8	nd	nd	85.0	nd	nd	nd	731.7	4.5	380.4	147.3
5/23/2001	143	nd	nd	643.2	18.1	546.1	nd	nd	nd	334.0	10.8	643.0	25.2
5/26/2001	146	923.5	123.7	483.1	9.8	143.4	6.2	nd	nd	516.3	20.6	497.4	nd
5/29/2001	149	748.8	96.3	290.3	10.7	129.2	0.0	nd	nd	547.7	7.5	468.0	27.8
6/1/2001	152	669.5	86.1	61.7	11.1	169.6	23.9	nd	nd	105.5	5.6	186.8	5.6
6/4/2001	155	1053.1	142.5	562.1	nd	182.3	20.7	2643.3	304.4	852.1	3.2	301.5	38.1
6/7/2001	158	798.2	121.6	155.7	8.4	265.7	24.5	3118.4	355.4	430.3	15.3	801.3	24.5

Appendix 2 Cont.

		High Snow						Low Snow					
Sampling Date	Julian Date	POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})		BioSi (mmol m^{-3})		POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})		BioSi (mmol m^{-3})	
				Avg	SD	Avg	SD			Avg	SD	Avg	SD
6/10/2001	161	671.4	87.01	352.0	7.5	139.8	22.4	2333.4	251.0	468.3	2.2	502.3	nd
6/13/2001	164	119.0	154.1	541.0	9.2	296.3	nd	3681.2	293.3	516.3	11.8	694.4	48.8
6/16/2001	167	1335.7	171.9	183.2	5.1	360.5	14.4	2630.8	196.8	821.4	20.1	538.2	25.3
6/19/2001	170	2260.5	207.1	520.7	4.1	399.4	5.0	2713.7	180.3	1069.8	26.1	433.0	3.3
6/22/2001	173	1417.9	162.7	222.6	5.2	132.1	3.0	1882.8	140.1	593.5	14.4	184.5	7.3
6/25/2001	176	903.3	95.23	240.9	17.2	105.7	nd	1824.9	156.3	356.4	25.2	232.5	6.8
6/28/2001	179	1264.4	109.4	82.1	5.4	148.8	nd	1597.4	131.0	554.0	11.7	161.7	8.4
7/1/2001	182	285.1	25.7	217.0	4.1	15.6	nd	nd	nd	242.3	1.6	4.3	nd

Appendix 3.
Suspended concentrations of chlorophyll *a* (total and > 5 µm), particulate organic carbon and nitrogen, and dissolved organic carbon at a first-year ice station in McDougall Sound, 2001. Averages (Avg) and standard deviations (SD) are given when applicable. Values in italics are estimated from the average POC/PON ratio. nd: no data.

Sampling Date	Julian Date	Depth	Total Chl *a* (mg m^{-3})		Chl *a* > 5 µm (mg m^{-3})		POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})	
			Avg	SD	Avg	SD			Avg	SD
05/09/01	129	2.5	0.20	0.01	0.19	0.03	12.63	1.16	122.4	1.59
05/09/01	129	5	0.24	0.01	0.20	0.05	9.42	nd	nd	nd
05/09/01	129	10	0.17	0.01	0.14	0.00	7.08	nd	nd	nd
05/09/01	129	25	0.06	0.01	0.05	0.01	*5.67*	0.62	nd	nd
05/12/01	132	2.5	0.22	0.02	0.22	0.06	9.12	0.91	118.48	1.58
05/12/01	132	5	0.13	0.02	0.13	0.04	5.00	0.42	nd	nd
05/12/01	132	10	0.13	0.06	0.08	0.00	6.67	0.57	nd	nd
05/12/01	132	25	0.08	0.00	0.06	0.02	6.55	0.77	nd	nd
05/15/01	135	2.5	0.20	0.01	0.14	0.01	6.90	0.59	108.27	1.97
05/15/01	135	5	0.14	0.06	0.07	0.00	6.63	0.60	nd	nd
05/15/01	135	10	0.08	0.01	0.06	0.02	5.10	0.63	nd	nd
05/15/01	135	25	0.06	0.00	0.05	0.00	*4.23*	0.46	nd	nd

Appendix 3. Cont.

Sampling Date	Julian Date	Depth	Total Chl *a* (mg m^{-3}) Avg	Total Chl *a* (mg m^{-3}) SD	Chl *a* > 5 µm (mg m^{-3}) Avg	Chl *a* > 5 µm (mg m^{-3}) SD	POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3}) Avg	DOC (mmol m^{-3}) SD
05/19/01	139	2.5	0.12	0.00	0.12	0.02	5.60	0.58	87.45	0.71
05/19/01	139	5	0.14	0.00	0.11	0.00	7.67	0.83	nd	nd
05/19/01	139	10	0.11	0.00	0.08	0.00	5.30	0.58	nd	nd
05/19/01	139	25	0.09	0.01	0.07	0.00	5.30	0.46	nd	nd
05/22/01	142	2.5	0.13	0.01	0.08	0.02	5.75	0.92	94.37	1.56
05/22/01	142	5	nd	nd	nd	nd	3.65	0.29	nd	nd
05/22/01	142	10	0.11	0.00	0.07	0.01	4.71	0.41	nd	nd
05/22/01	142	25	0.08	0.00	0.08	0.02	3.69	0.32	nd	nd
05/25/01	145	2.5	0.26	0.11	0.23	0.01	8.31	nd	106.01	0.89
05/25/01	145	5	0.21	0.05	0.12	0.02	8.60	0.85	nd	nd
05/25/01	145	10	0.11	0.01	0.11	0.02	3.01	0.33	nd	nd
05/25/01	145	25	0.07	0.01	0.07	0.04	3.46	0.29	nd	nd
05/28/01	148	2.5	1.82	0.00	1.82	0.09	11.81	1.06	114.40	1.88
05/28/01	148	5	0.84	0.01	0.82	0.01	7.00	0.69	nd	nd
05/28/01	148	10	0.15	0.01	0.15	0.02	4.42	0.53	nd	nd

Appendix 3 Cont.

Sampling Date	Julian Date	Depth	Total Chl *a* (mg m^{-3})		Chl *a* > 5 µm (mg m^{-3})		POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})	
			Avg	SD	Avg	SD			Avg	SD
05/28/01	148	25	0.11	0.00	0.10	0.00	3.61	0.40	nd	nd
05/31/01	151	2.5	1.69	0.15	1.69	0.18	nd	nd	147.10	4.43
05/31/01	151	5	1.01	0.35	0.87	0.05	28.31	nd	nd	nd
05/31/01	151	10	0.18	0.02	0.14	0.01	4.92	0.56	nd	nd
05/31/01	151	25	0.08	0.02	0.05	0.00	5.51	0.90	nd	nd
06/03/01	154	2.5	0.44	0.01	0.37	0.04	7.50	0.79	93.82	0.80
06/03/01	154	5	0.23	0.02	0.24	0.04	6.45	0.72	nd	nd
06/03/01	154	10	0.11	0.00	0.10	0.02	5.53	0.61	nd	nd
06/03/01	154	25	0.09	0.02	0.07	0.02	5.31	0.76	nd	nd
06/06/01	157	2.5	0.27	0.02	0.24	0.12	6.58	0.63	117.26	1.49
06/06/01	157	5	0.14	0.01	0.14	0.00	5.32	0.58	nd	nd
06/06/01	157	10	0.13	0.00	0.08	0.01	5.48	nd	nd	nd
06/06/01	157	25	0.09	0.00	0.07	0.02	4.37	0.45	nd	nd
06/09/01	160	2.5	6.67	0.21	6.67	0.19	28.06	4.06	122.04	1.48
06/09/01	160	5	0.57	0.01	0.54	0.07	5.32	0.48	nd	nd

Appendix 3 Cont.

Sampling Date	Julian Date	Depth	Total Chl *a* (mg m^{-3}) Avg	Total Chl *a* (mg m^{-3}) SD	Chl *a* > 5 µm (mg m^{-3}) Avg	Chl *a* > 5 µm (mg m^{-3}) SD	POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3}) Avg	DOC (mmol m^{-3}) SD
06/09/01	160	10	0.46	0.07	0.27	0.10	nd	nd	nd	nd
06/09/01	160	25	0.17	0.02	0.14	0.00	4.92	0.43	nd	nd
06/12/01	163	2.5	1.38	0.07	1.38	0.11	12.91	1.35	225.07	4.74
06/12/01	163	5	0.28	0.03	0.24	0.02	6.14	0.73	nd	nd
06/12/01	163	10	0.29	0.05	0.24	0.02	5.70	0.68	nd	nd
06/12/01	163	25	0.13	0.00	0.10	0.00	4.34	0.54	nd	nd
06/15/01	166	2.5	10.73	0.60	10.73	0.31	78.56	7.73	118.70	3.17
06/15/01	166	5	1.14	0.12	1.14	0.34	10.49	1.23	nd	nd
06/15/01	166	10	0.35	0.06	0.35	0.02	7.97	0.92	nd	nd
06/15/01	166	25	0.10	0.00	0.10	0.01	4.25	nd	nd	nd
06/18/01	169	2.5	0.31	0.00	0.31	0.02	7.64	0.80	178.78	1.63
06/18/01	169	5	0.22	0.02	0.18	0.03	5.72	0.70	nd	nd
06/18/01	169	10	0.19	0.03	0.15	0.01	6.43	0.68	nd	nd
06/18/01	169	25	0.18	0.00	0.18	0.01	4.85	0.59	nd	nd
06/21/01	172	2.5	0.62	0.21	0.36	0.04	8.12	1.02	90.67	1.65

Appendix 3 Cont.

Sampling Date	Julian Date	Depth	Total Chl *a* (mg m^{-3})		Chl *a* > 5 µm (mg m^{-3})		POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})	
			Avg	SD	Avg	SD			Avg	SD
06/21/01	172	5	0.25	0.02	0.22	0.01	nd	nd	nd	nd
06/21/01	172	10	0.27	0.00	0.23	0.02	6.86	0.78	nd	nd
06/21/01	172	25	0.29	0.03	0.23	0.43	5.56	0.62	nd	nd
06/24/01	175	2.5	0.50	0.03	0.50	0.07	11.23	1.35	92.72	1.15
06/24/01	175	5	0.31	0.01	0.25	0.00	8.42	0.78	nd	nd
06/24/01	175	10	0.29	0.03	0.29	0.01	7.48	0.79	nd	nd
06/24/01	175	25	0.27	0.00	0.27	0.03	6.61	0.74	nd	nd
06/27/01	178	2.5	0.47	0.00	0.36	0.01	9.89	1.32	104.83	1.42
06/27/01	178	5	0.31	0.02	0.16	0.01	9.64	1.31	nd	nd
06/27/01	178	10	0.37	0.05	0.18	0.02	8.78	0.97	nd	nd
06/27/01	178	25	0.30	0.03	0.15	0.01	5.36	0.60	nd	nd
06/30/01	181	2.5	0.51	0.03	0.38	0.00	20.59	2.43	111.87	1.74
06/30/01	181	5	0.34	0.00	0.18	0.01	11.54	nd	nd	nd
06/30/01	181	10	0.32	0.02	0.11	0.04	nd	nd	nd	nd
06/30/01	181	25	0.33	0.01	0.05	0.00	9.73	1.71	nd	nd

Appendix 3 Cont.

Sampling Date	Julian Date	Depth	Total Chl *a* (mg m^{-3})		Chl *a* > 5 µm (mg m^{-3})		POC (mmol m^{-3})	PON (mmol m^{-3})	DOC (mmol m^{-3})	
			Avg	SD	Avg	SD			Avg	SD
07/03/01	184	2.5	0.54	0.02	0.35	0.02	30.12	3.93	100.69	1.12
07/03/01	184	5	0.61	0.00	0.36	0.00	14.53	1.47	nd	nd
07/03/01	184	10	0.64	0.03	0.32	0.01	8.09	0.82	nd	nd
07/03/01	184	25	0.45	0.01	0.17	0.02	12.34	1.50	nd	nd
07/06/01	187	2.5	2.45	0.04	2.30	0.03	24.55	3.29	165.39	2.26
07/06/01	187	5	2.55	0.16	1.94	0.08	25.34	3.50	nd	nd
07/06/01	187	10	2.38	0.16	1.57	0.04	16.91	2.05	nd	nd
07/06/01	187	25	1.84	0.01	1.08	0.02	25.07	2.75	nd	nd

Appendix 4.
Sinking fluxes of chlorophyll *a* (total and > 5 µm) (mg m^{-2} d^{-1}), particulate organic carbon and nitrogen, and biogenic silica (mmol m^{-2} d^{-1}) at a first-year ice station in McDougall Sound, 2001. Averages (Avg) and standard deviations (SD) are given when applicable. nd: no data.

Date In	Date Out	Julian Date In/Out	Depth	Total Chl *a* (mg m^{-2} d^{-1}) Avg	Total Chl *a* (mg m^{-2} d^{-1}) SD	Chl *a* > 5 µm (mg m^{-2} d^{-1})	POC (mmol m^{-2} d^{-1})	PON (mmol m^{-2} d^{-1})	BioSi (mmol m^{-2} d^{-1}) Avg	BioSi (mmol m^{-2} d^{-1}) SD
5/8/2001	5/11/2001	128/131	2.5	0.45	0.01	0.42	11.60	0.84	0.77	0.66
5/8/2001	5/11/2001	128/131	5	0.51	0.01	0.51	7.94	0.84	0.57	0.32
5/8/2001	5/11/2001	128/131	25	0.68	0.02	0.64	8.16	nd	0.59	0.06
5/11/2001	5/14/2001	131/134	2.5	0.14	0.07	0.07	5.72	0.58	0.42	nd
5/11/2001	5/14/2001	131/134	5	0.14	0.01	0.08	4.40	0.46	0.34	nd
5/11/2001	5/14/2001	131/134	25	0.13	0.04	0.11	3.65	0.33	0.31	0.36
5/14/2001	5/18/2001	134/138	2.5	0.06	0.01	0.05	4.98	0.62	0.40	nd
5/14/2001	5/18/2001	134/138	5	0.06	0.00	0.03	7.09	1.09	0.41	nd
5/14/2001	5/18/2001	134/138	25	0.06	0.01	0.06	2.08	0.25	0.39	nd
5/18/2001	5/21/2001	138/141	2.5	0.12	0.03	0.07	2.09	0.39	0.40	nd
5/18/2001	5/21/2001	138/141	5	0.14	0.01	0.09	3.83	0.43	0.48	0.10
5/18/2001	5/21/2001	138/141	25	0.19	0.01	0.13	3.61	0.31	0.57	nd
5/21/2001	5/24/2001	141/144	2.5	0.14	0.01	0.12	6.46	0.75	0.43	nd

Appendix 4 Cont.

Date In	Date Out	Julian Date In/Out	Depth	Total Chl *a* (mg m^{-2} d^{-1}) Avg	Total Chl *a* (mg m^{-2} d^{-1}) SD	Chl *a* > 5 µm (mg m^{-2} d^{-1})	POC (mmol m^{-2} d^{-1})	PON (mmol m^{-2} d^{-1})	BioSi (mmol m^{-2} d^{-1}) Avg	BioSi (mmol m^{-2} d^{-1}) SD
5/21/2001	5/24/2001	141/144	5	0.15	0.02	0.15	3.02	0.41	0.23	0.22
5/21/2001	5/24/2001	141/144	25	0.18	0.01	0.18	3.77	0.37	0.21	nd
5/24/2001	5/27/2001	144/147	2.5	0.31	0.02	0.30	3.60	0.46	0.20	0.07
5/24/2001	5/27/2001	144/147	5	0.53	0.00	0.45	4.46	0.57	0.40	0.11
5/24/2001	5/27/2001	144/147	25	0.45	0.08	0.40	9.09	0.83	0.29	nd
5/27/2001	5/30/2001	147/150	2.5	0.33	0.04	0.33	4.69	0.74	0.46	0.07
5/27/2001	5/30/2001	147/150	5	0.13	0.01	0.12	3.19	0.46	0.10	0.06
5/27/2001	5/30/2001	147/150	25	0.37	0.01	0.37	3.61	0.38	0.33	0.43
5/30/2001	6/2/2001	150/153	2.5	0.66	0.07	0.66	7.38	1.12	0.75	0.34
5/30/2001	6/2/2001	150/153	5	0.91	0.05	0.91	8.44	1.47	1.37	0.24
5/30/2001	6/2/2001	150/153	25	0.13	0.01	0.13	nd	1.16	0.28	nd
6/2/2001	6/5/2001	153/156	2.5	0.11	0.01	0.11	5.18	0.78	0.25	0.24
6/2/2001	6/5/2001	153/156	5	0.23	0.02	0.21	6.19	0.76	0.2	0.13
6/2/2001	6/5/2001	153/156	25	0.14	0.01	0.14	2.91	0.27	nd	nd
6/5/2001	6/8/2001	156/159	2.5	0.87	0.03	0.75	5.25	0.85	1.29	nd

Appendix 4 Cont.

Date In	Date Out	Julian Date In/Out	Depth	Total Chl *a* (mg m^{-2} d^{-1}) Avg	Total Chl *a* (mg m^{-2} d^{-1}) SD	Chl *a* > 5 µm (mg m^{-2} d^{-1})	POC (mmol m^{-2} d^{-1})	PON (mmol m^{-2} d^{-1})	BioSi (mmol m^{-2} d^{-1}) Avg	BioSi (mmol m^{-2} d^{-1}) SD
6/5/2001	6/8/2001	156/159	5	0.23	0.03	0.23	3.52	0.44	1.01	nd
6/5/2001	6/8/2001	156/159	25	0.27	0.02	0.27	3.46	0.30	1.11	nd
6/8/2001	6/11/2001	159/162	2.5	1.01	0.02	0.96	6.70	0.80	1.94	1.58
6/8/2001	6/11/2001	159/162	5	1.07	0.03	1.07	7.21	0.93	2.12	1.81
6/8/2001	6/11/2001	159/162	25	0.73	0.00	0.73	4.26	0.54	1.20	0.02
6/11/2001	6/14/2001	162/165	2.5	1.41	0.04	1.41	11.48	1.35	2.80	2.65
6/11/2001	6/14/2001	162/165	5	1.77	0.03	1.30	18.67	1.93	nd	5.01
6/11/2001	6/14/2001	162/165	25	0.93	0.01	0.88	6.90	0.68	1.93	1.47
6/14/2001	6/17/2001	165/168	2.5	0.83	0.01	0.83	8.42	0.85	1.40	nd
6/14/2001	6/17/2001	165/168	5	0.93	0.00	0.93	8.62	0.97	1.87	1.44
6/14/2001	6/17/2001	165/168	25	1.44	0.02	1.44	13.04	1.57	2.27	0.56
6/17/2001	6/20/2001	168/171	2.5	1.14	0.03	1.14	13.26	1.37	2.32	0.93
6/17/2001	6/20/2001	168/171	5	1.63	0.01	1.58	17.02	1.73	3.27	1.38
6/17/2001	6/20/2001	168/171	25	1.13	0.00	1.13	12.19	1.76	2.47	0.50
6/20/2001	6/23/2001	171/174	2.5	4.34	0.03	4.25	39.28	3.09	3.36	2.93

Appendix 4 Cont.

Date In	Date Out	Julian Date In/Out	Depth	Total Chl *a* (mg m^{-2} d^{-1}) Avg	Total Chl *a* (mg m^{-2} d^{-1}) SD	Chl *a* > 5 µm (mg m^{-2} d^{-1})	POC (mmol m^{-2} d^{-1})	PON (mmol m^{-2} d^{-1})	BioSi (mmol m^{-2} d^{-1}) Avg	BioSi (mmol m^{-2} d^{-1}) SD
6/20/2001	6/23/2001	171/174	5	3.89	0.00	3.87	40.02	2.90	3.75	0.72
6/20/2001	6/23/2001	171/174	25	3.76	0.10	3.76	36.63	2.82	3.72	nd
6/23/2001	6/26/2001	174/177	2.5	4.20	0.02	4.20	53.89	3.85	3.94	1.40
6/23/2001	6/26/2001	174/177	5	4.18	0.06	4.18	48.73	nd	3.96	0.92
6/23/2001	6/26/2001	174/177	25	3.74	0.02	3.60	nd	nd	3.27	0.39
6/26/2001	6/29/2001	177/180	2.5	1.91	0.09	1.89	27.49	2.35	3.46	nd
6/26/2001	6/29/2001	177/180	5	1.65	0.04	1.65	24.39	2.18	2.73	nd
6/26/2001	6/29/2001	177/180	25	1.76	0.04	1.76	21.90	1.72	2.46	nd
6/29/2001	7/2/2001	180/183	2.5	1.13	0.06	1.13	15.35	1.46	2.60	nd
6/29/2001	7/2/2001	180/183	5	0.68	0.04	0.63	12.29	1.26	3.11	nd
6/29/2001	7/2/2001	180/183	25	0.80	0.04	0.67	9.93	1.08	1.91	0.06
7/2/2001	7/5/2001	183/186	2.5	2.08	0.13	1.82	15.25	1.92	1.77	0.17
7/2/2001	7/5/2001	183/186	5	1.55	0.07	1.55	13.14	1.70	1.76	nd
7/2/2001	7/5/2001	183/186	25	0.39	0.00	0.39	6.73	0.84	0.80	nd